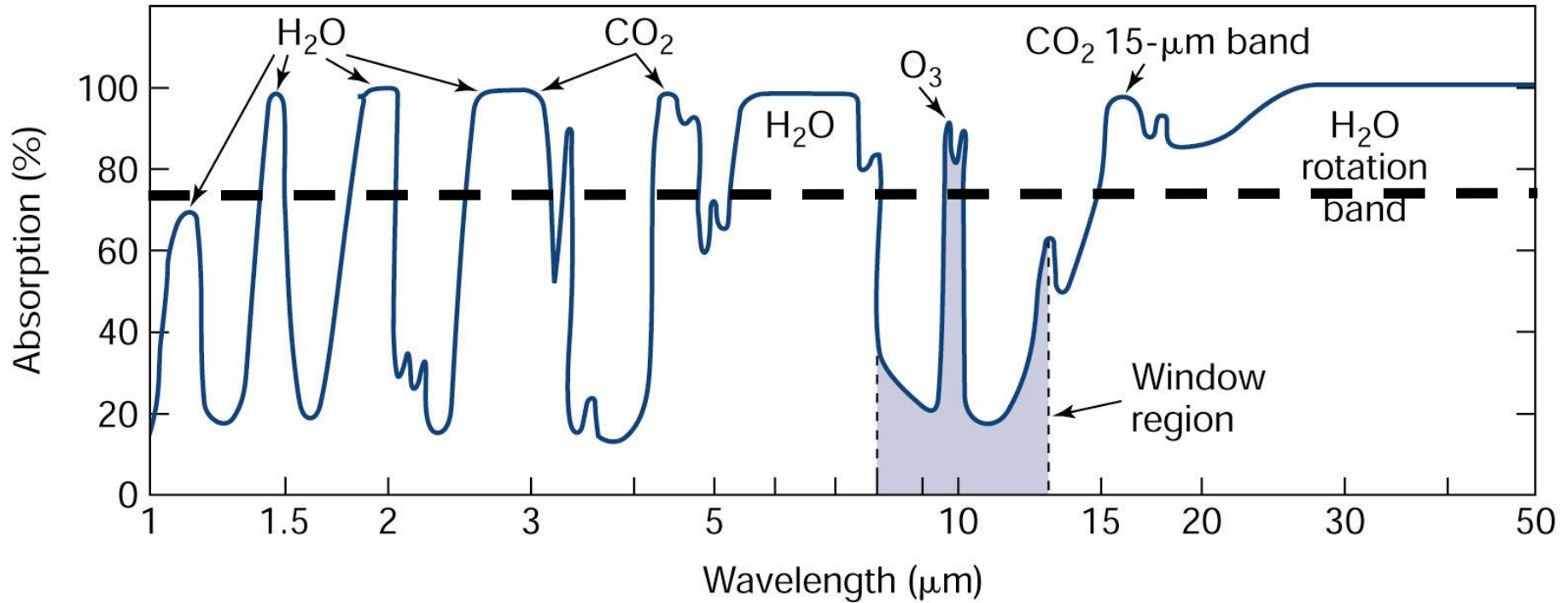


What gases cause the greenhouse effect?

- Gases that absorb IR radiation are greenhouse gases (GHG)
- But not all gases that absorb IR radiation are effective GHG

Atmosphere's Absorption Spectrum

Absorptivity versus wavelength



— — — Indicates absorptivity we assumed in our 1-layer model

Water (H₂O) as “most important” GHG

GHG Ranking Factors

1. **Amount:** more GHG, more radiation can be absorbed

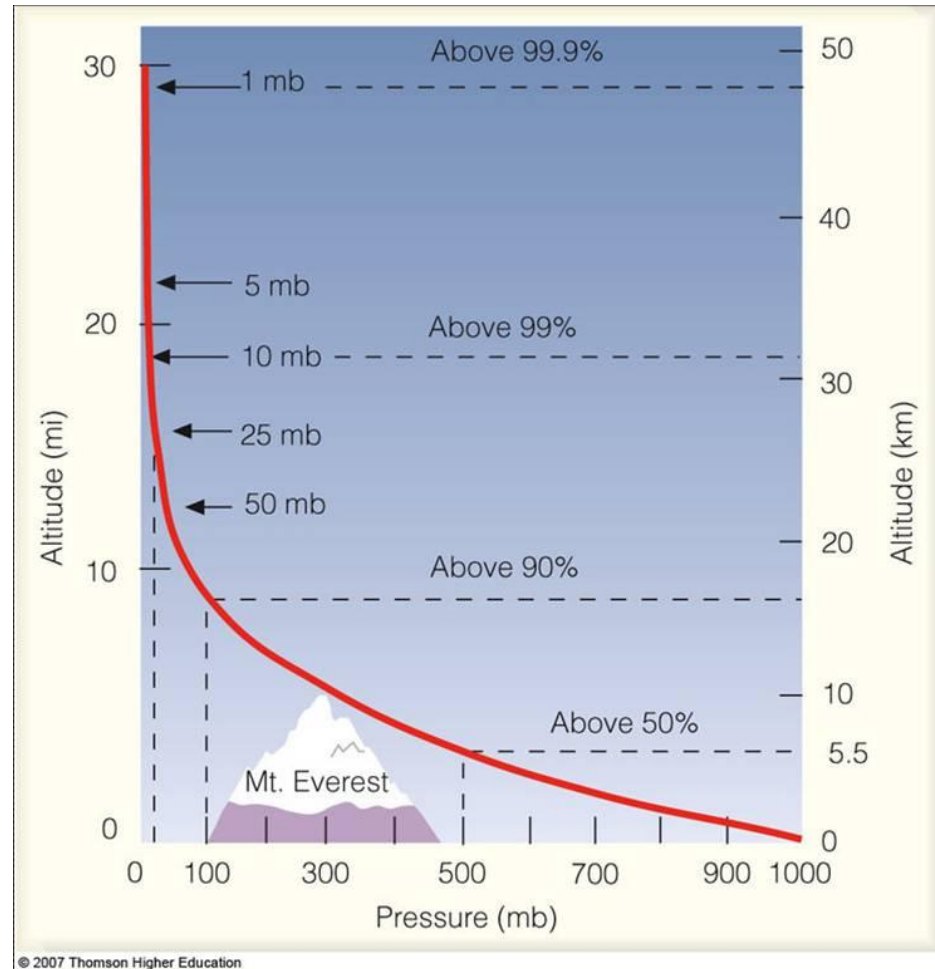
GHG Ranking Factors

1. **Amount:** more GHG, more radiation can be absorbed
2. **Ability:** depends on wavelength and GHG
Absorptivity (ϵ) ~ **Amount*****Ability**

GHG Ranking Factors

- 1. Amount:** more GHG, more radiation can be absorbed
- 2. Ability:** depends on wavelength and GHG
Absorptivity (ϵ) ~ **Amount*****Ability**
- 3. Location:** both where in altitude and where in outgoing radiation spectrum (wavelength)

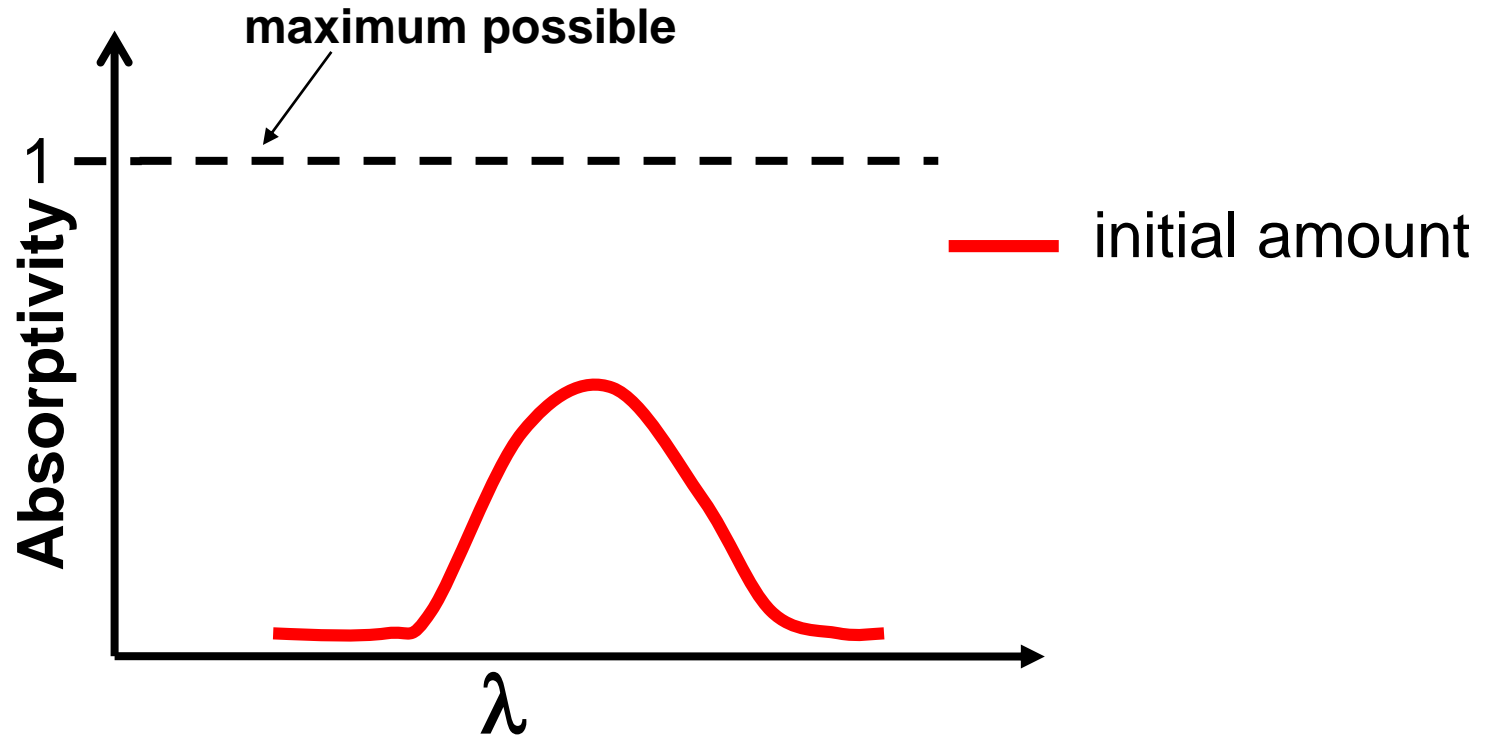
“Amounts” measured by Pressure



GHG Ranking Factors

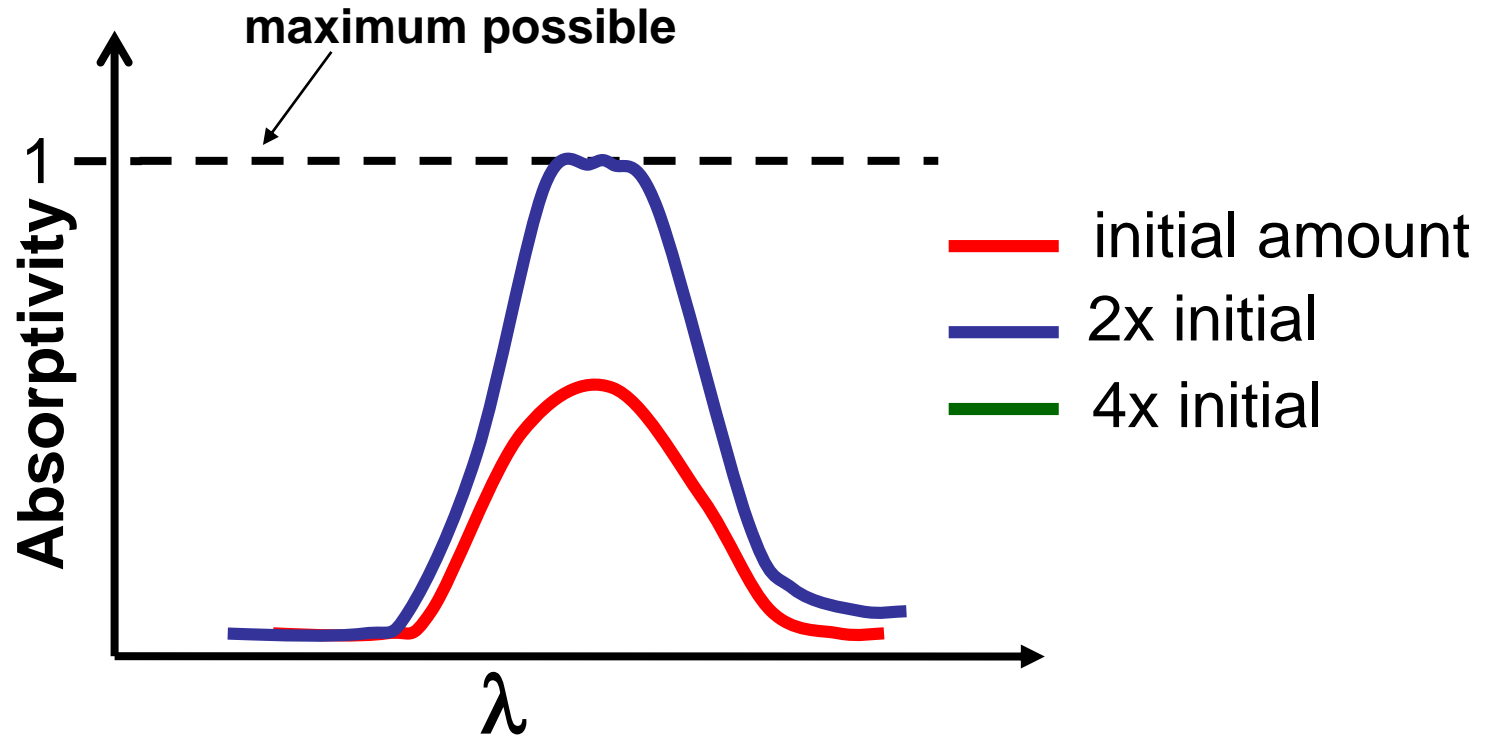
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“Ability”: Band Saturation



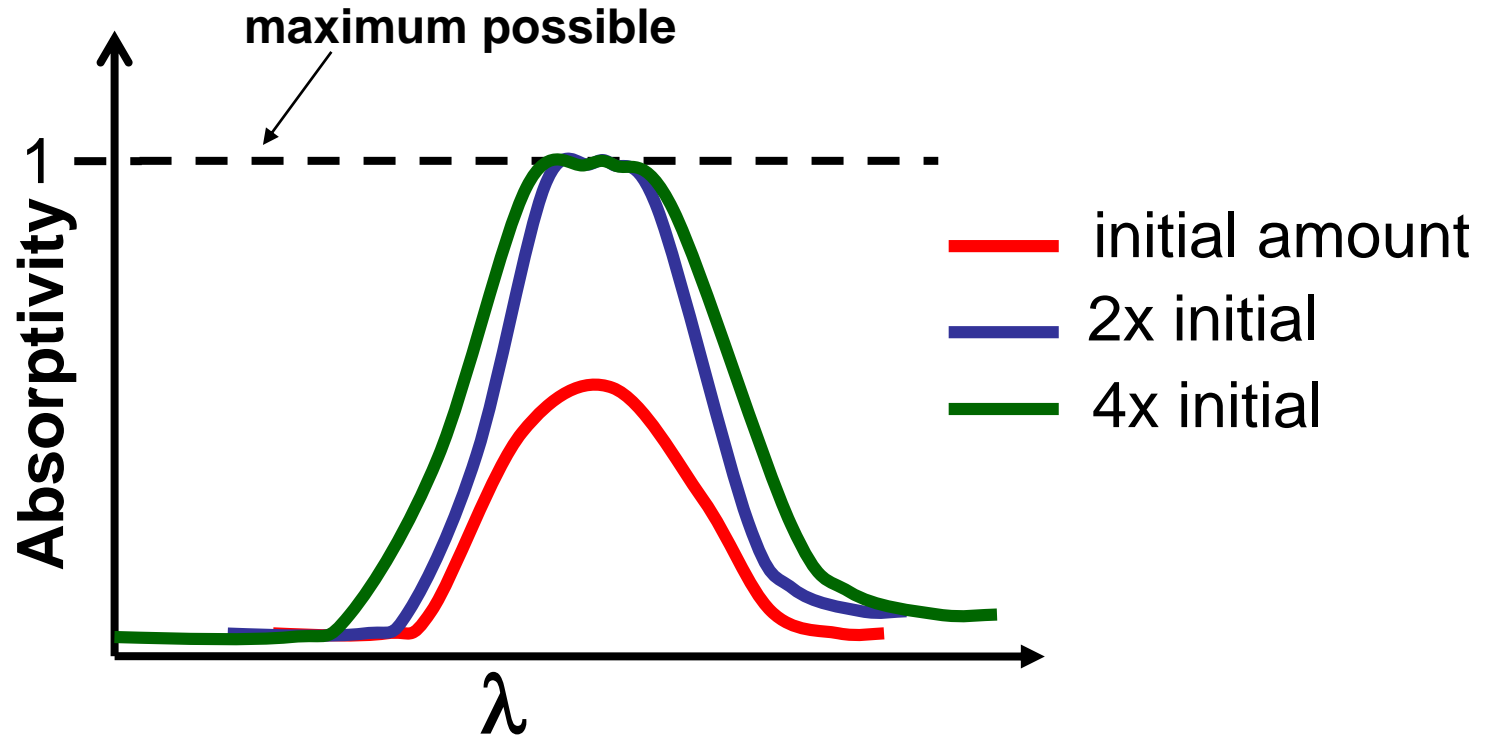
Increasing amount of a GHG does not lead to linear increases in absorptivity

“Ability”: Band Saturation



Increasing amount of a GHG does not lead to linear increases in absorptivity

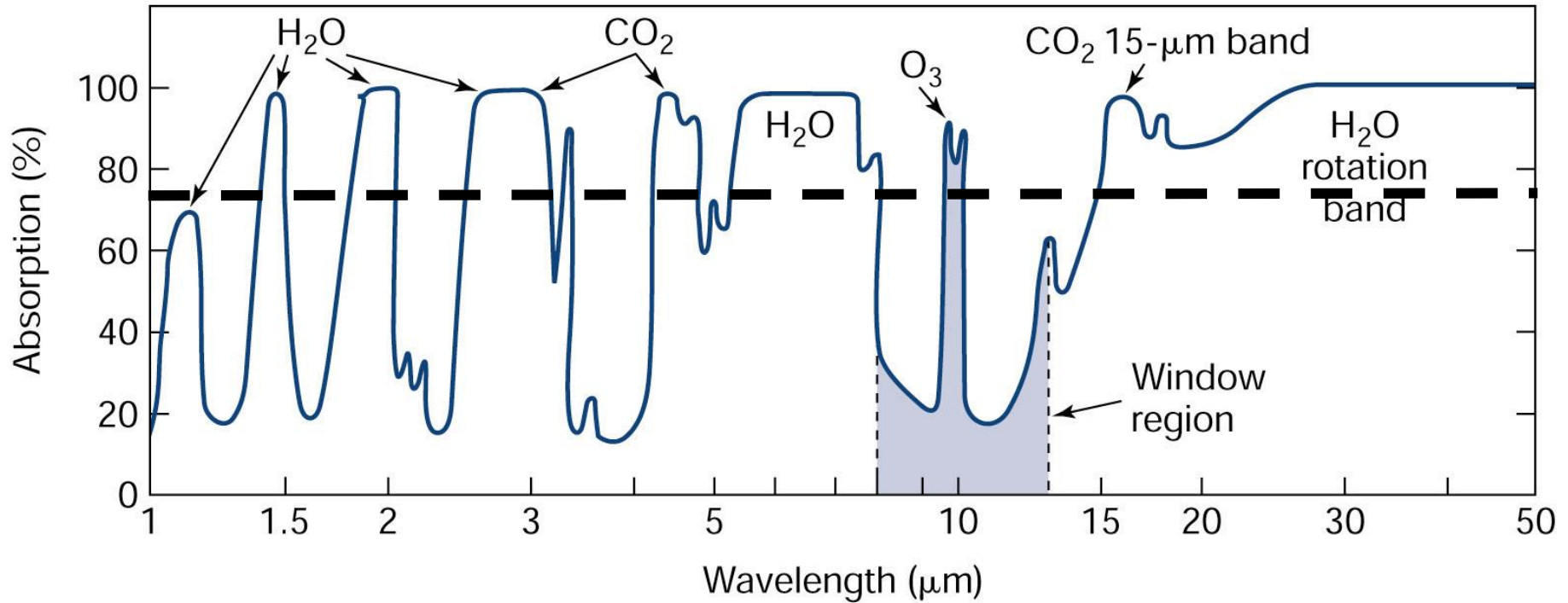
“Ability”: Band Saturation



Increasing amount of a GHG does not lead to linear increases in absorptivity

Atmosphere's Absorption Spectrum

Absorptivity versus wavelength



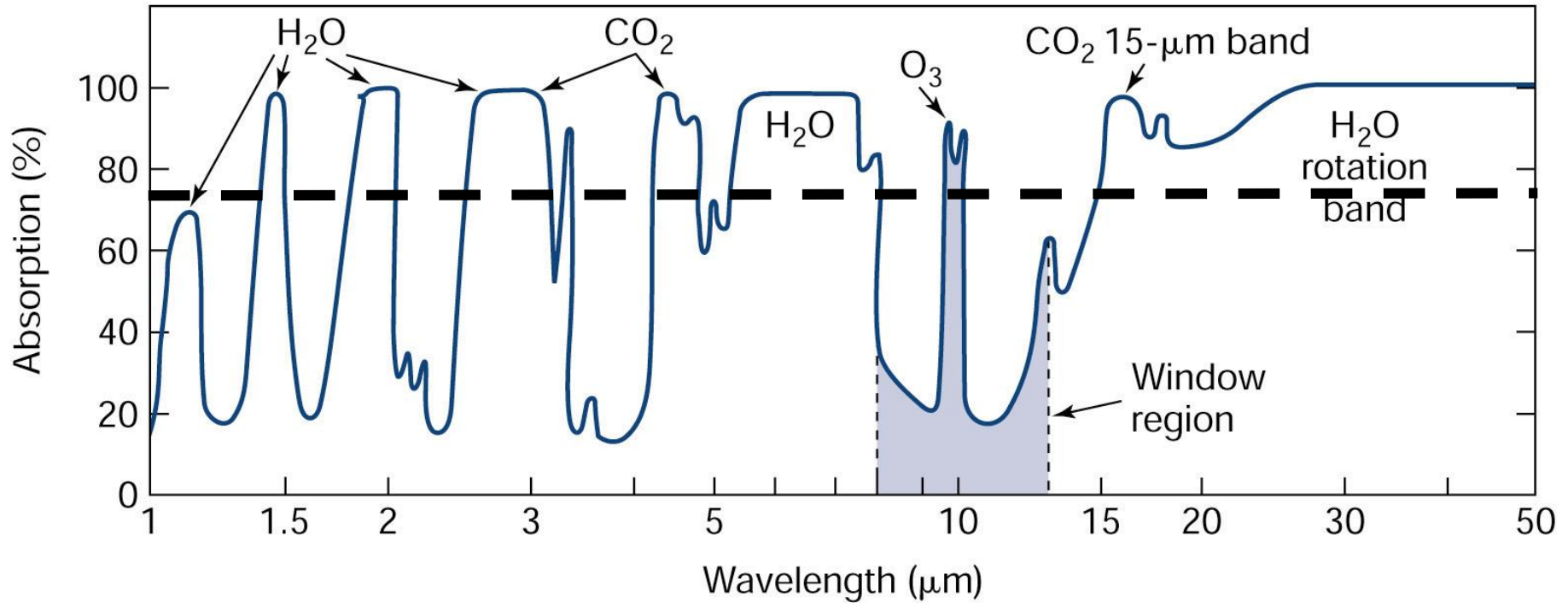
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Atmosphere's Absorption Spectrum

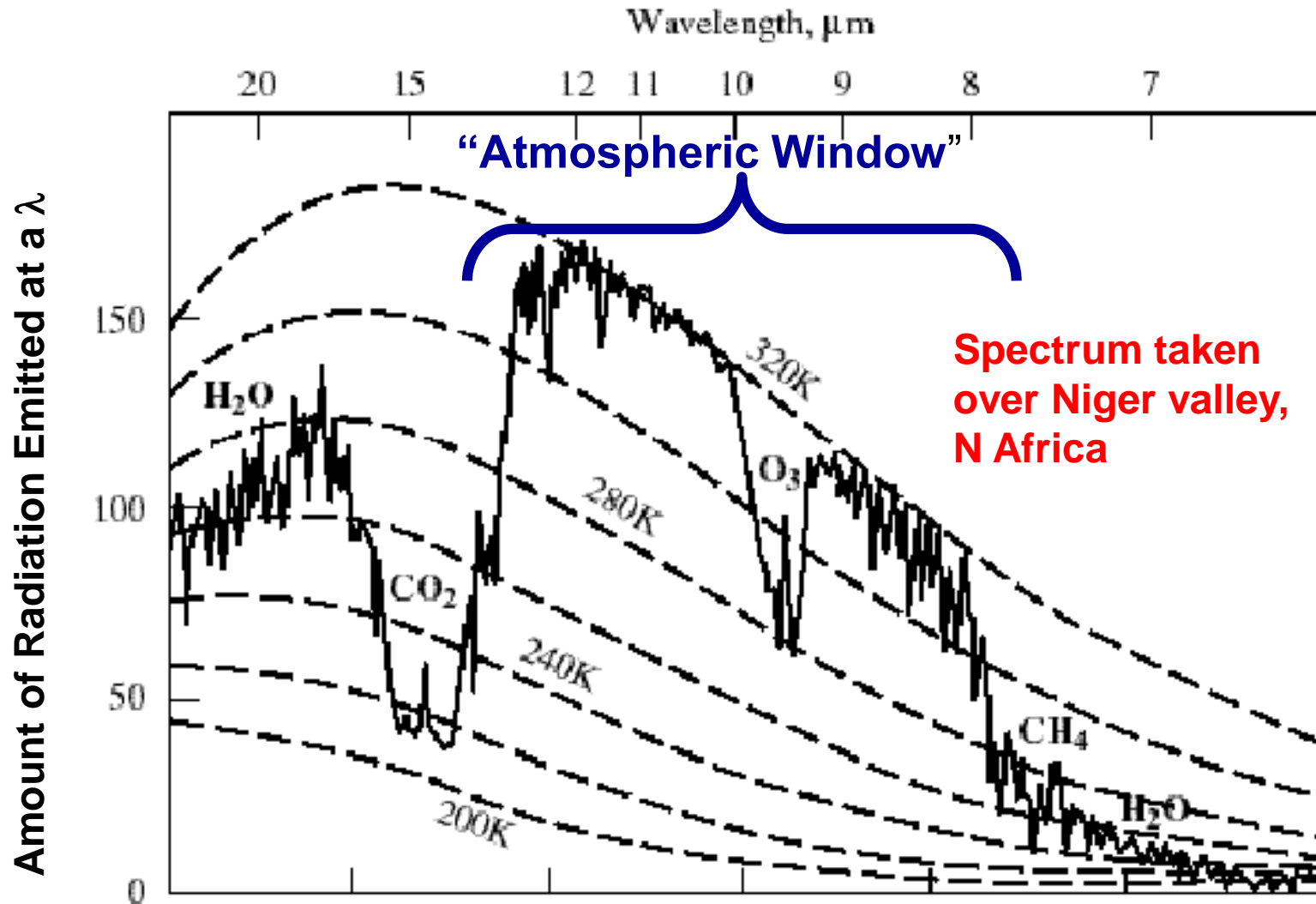
Absorptivity versus wavelength



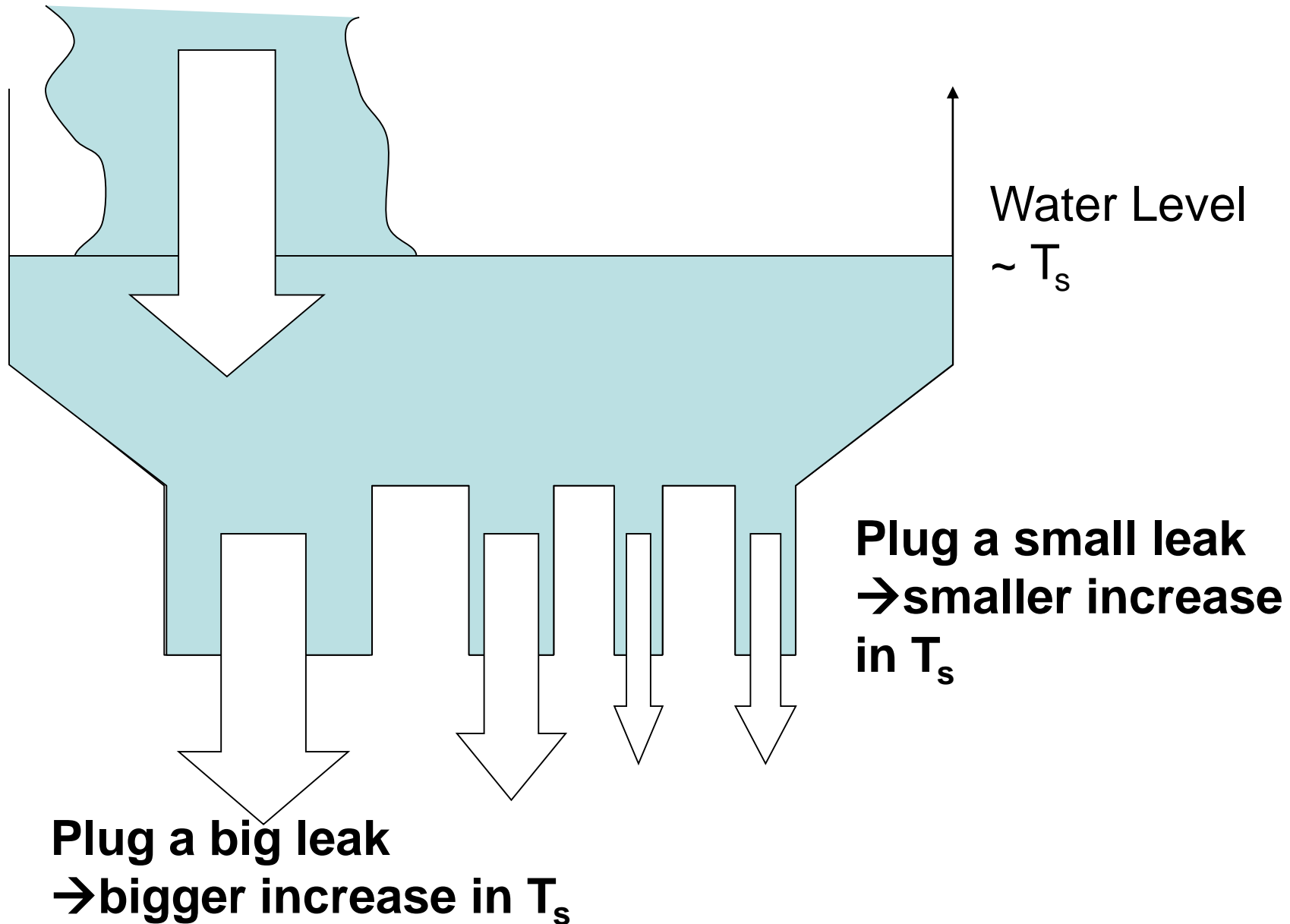
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Emission Spectrum of Earth Taken From Space

Emission from cold atmosphere and warm surface



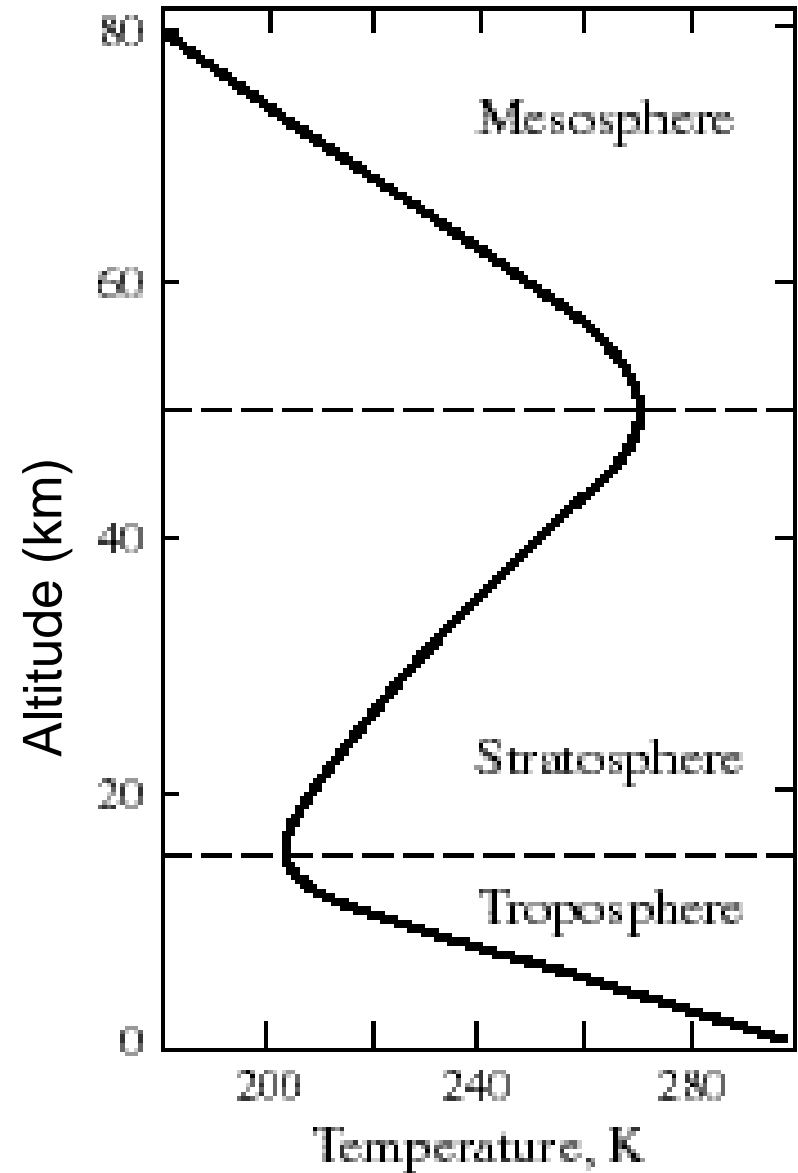
GHG Ranking: Wavelength “Location”



Altitude Location: Atmospheric Temperature

Amount of radiation emitted by atmospheric gases will depend on their temperature

Mean values for 30°N, March



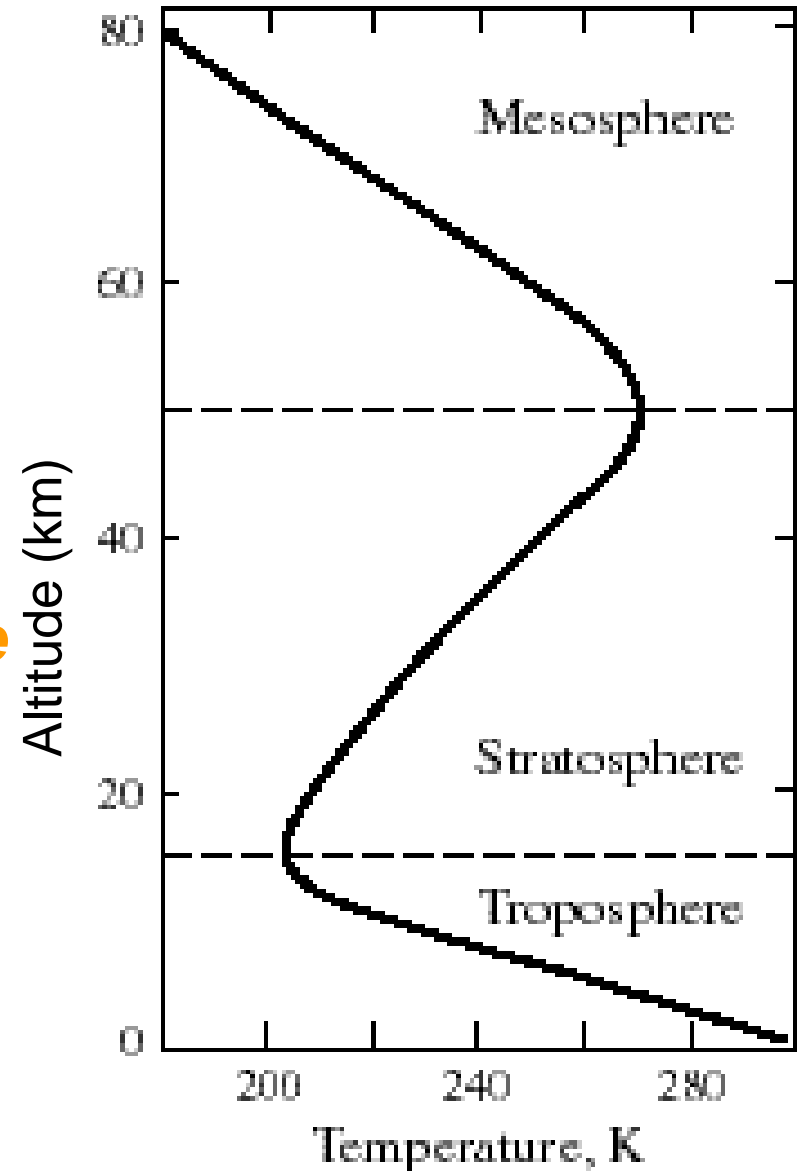
Altitude Location: Atmospheric Temperature

Amount of radiation emitted by atmospheric gases will depend on their temperature

Solar heating of the surface sets tropospheric temperature profile

Temperature decreases with increasing altitude in troposphere

Mean values for 30°N, March



Altitude Location: Atmospheric Temperature

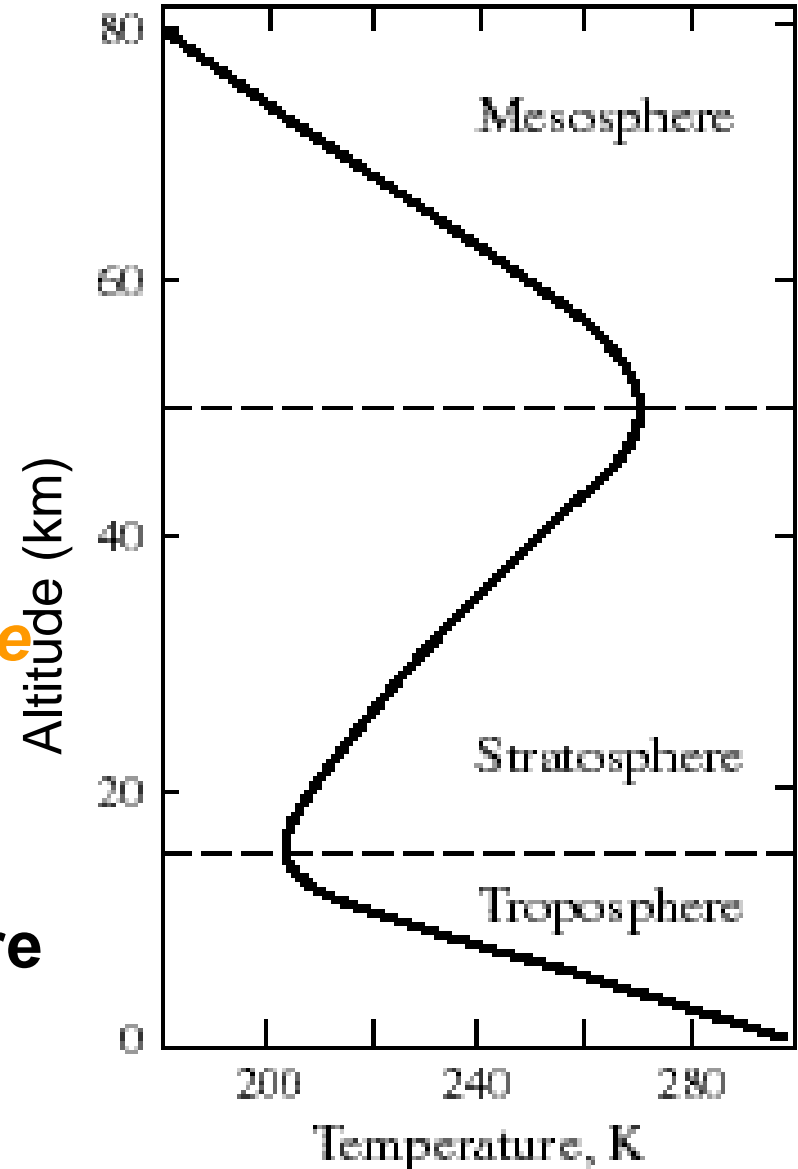
Amount of radiation emitted by atmospheric gases will depend on their temperature

Solar heating of the surface sets tropospheric temperature profile

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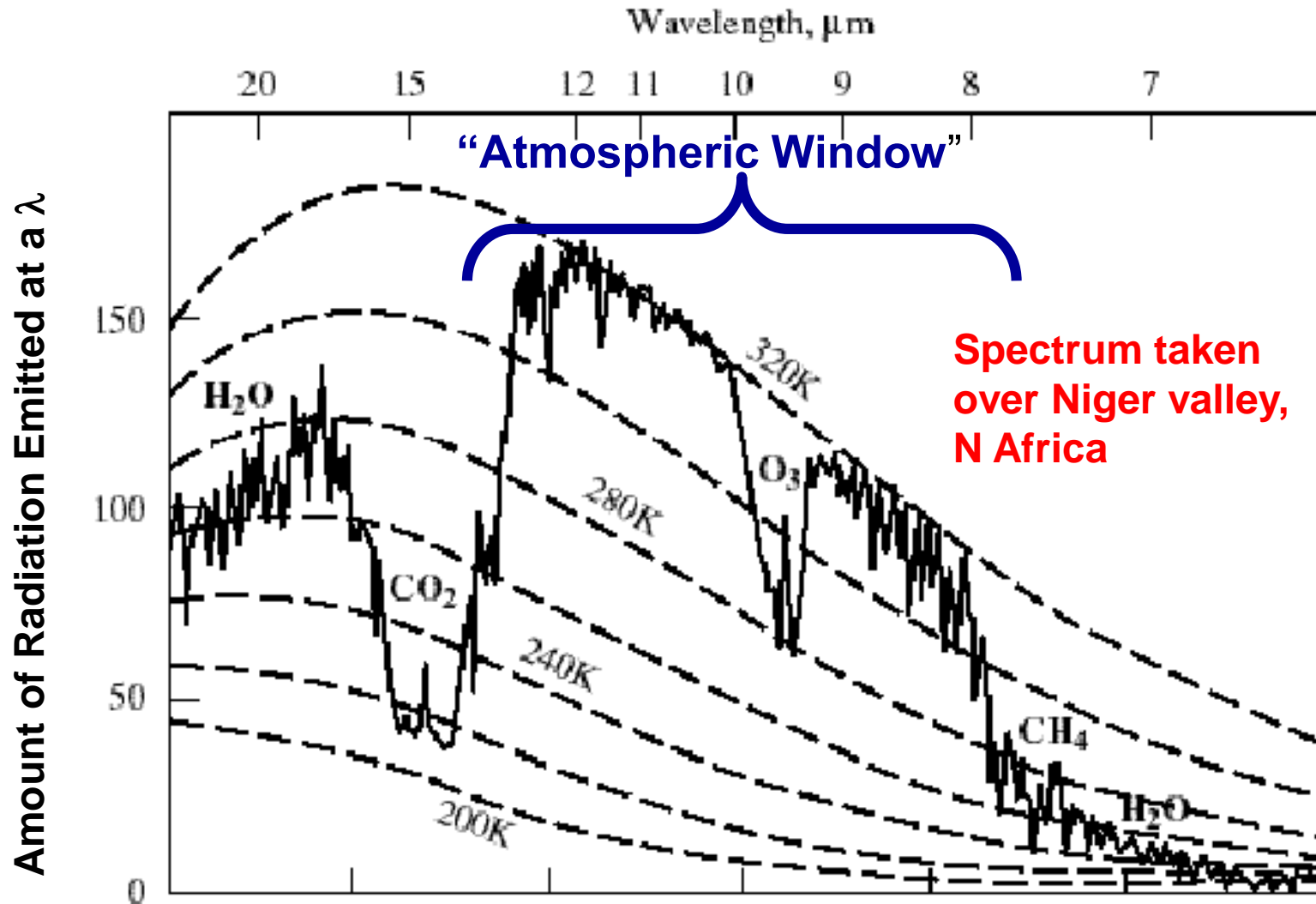
Absorption of short-wave solar radiation by ozone in stratosphere causes temperature to increase

Mean values for 30°N, March



Emission Spectrum of Earth Taken From Space

Emission from cold atmosphere and warm surface



Poll

W

At wavelengths absorbed by H₂O vapor, Earth emission spectrum looks like it has a T ~ 260 – 280 K, while at those absorbed by CO₂ it looks like T ~ 220 K, therefore

 **Poll locked.** Responses not accepted.

Water vapor is confined to lower in the atmosphere than CO₂

Water vapor is more effective at absorbing the wavelengths it emits.

CO₂ is less effective at emitting the radiation it does absorb

Visual settings 


Activate 


Show results 


Show correct 

Lock 

Clear results 

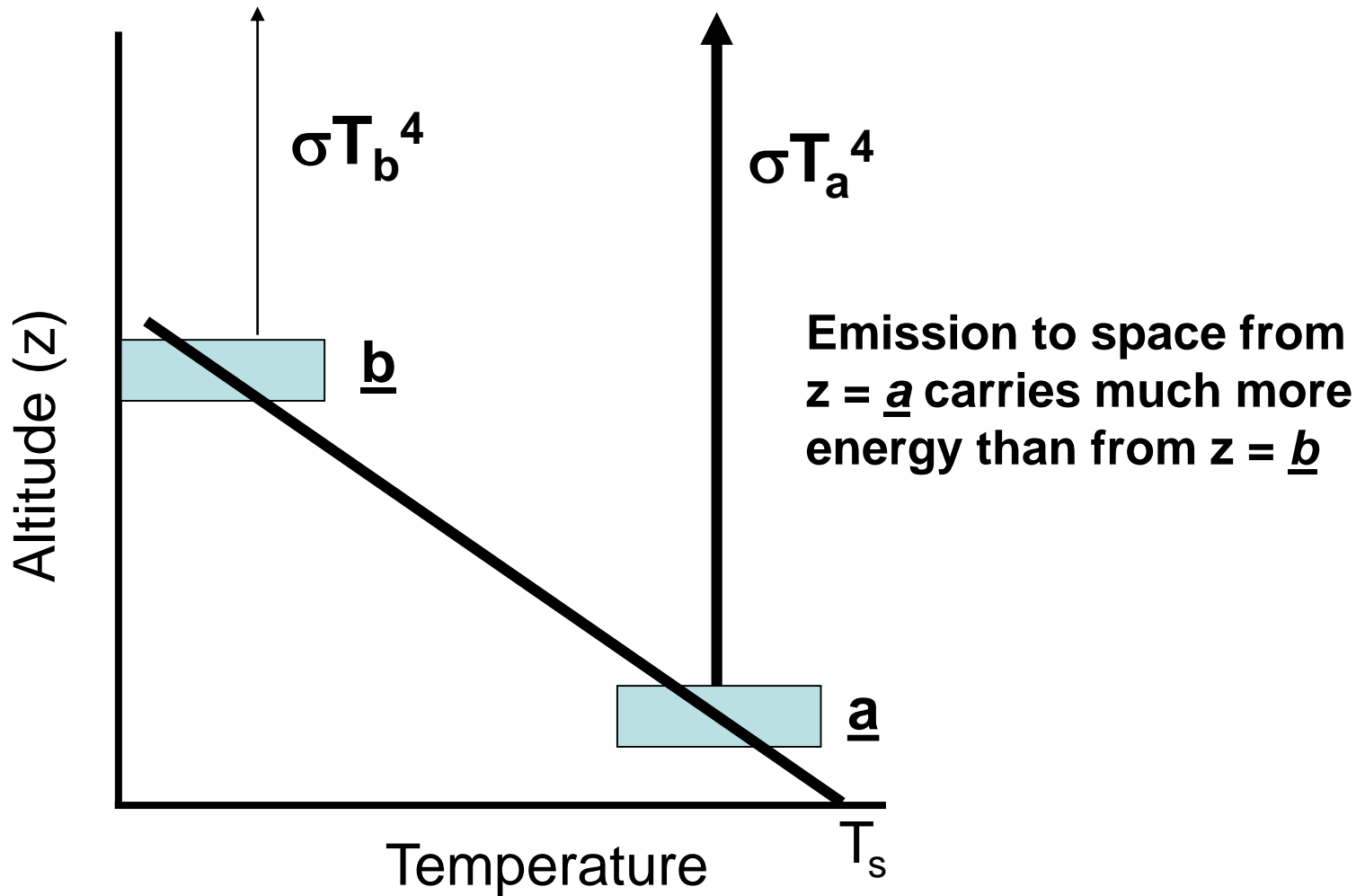
Fullscreen 

Next 

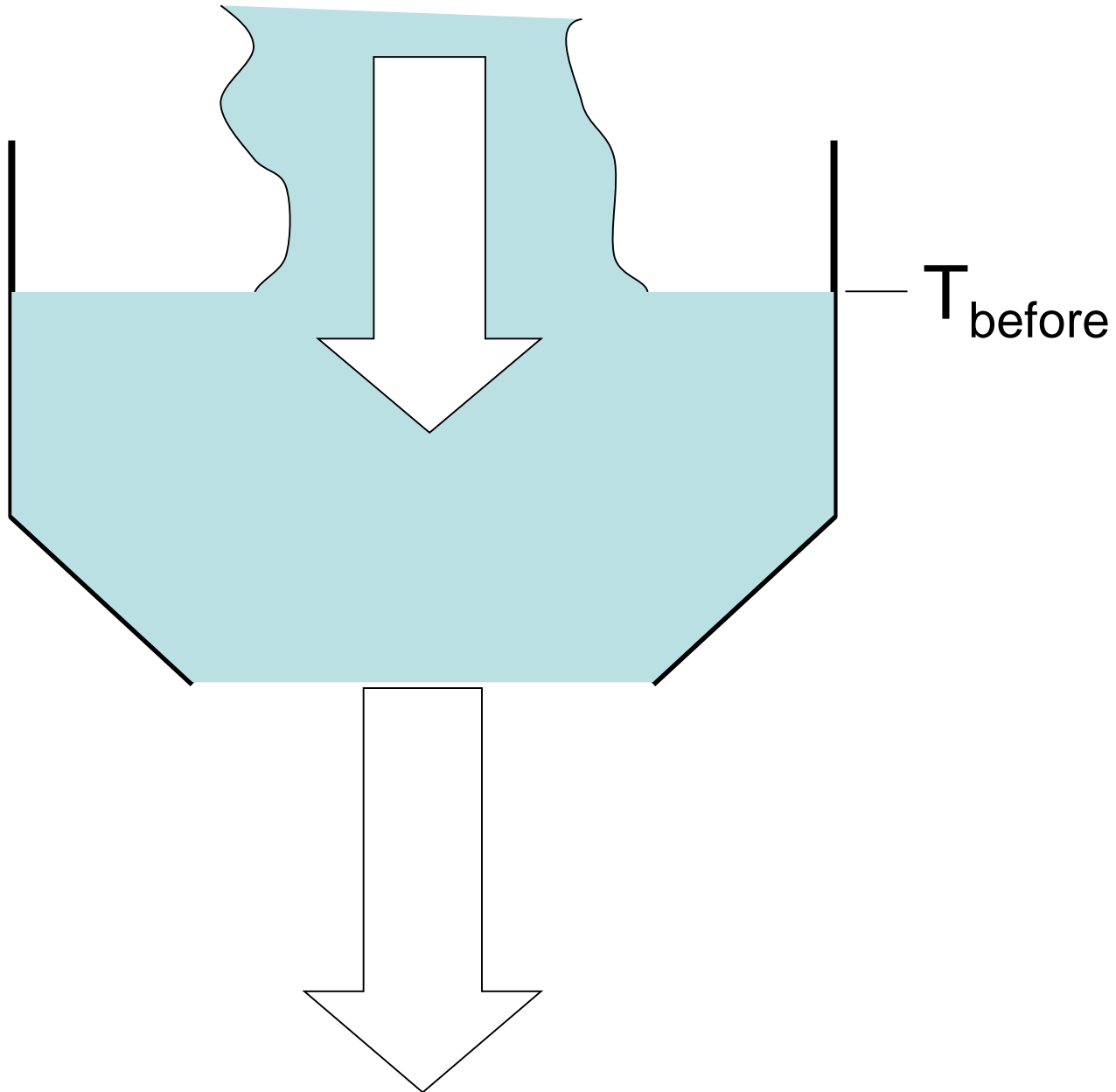
Previous 

Total Results: 81

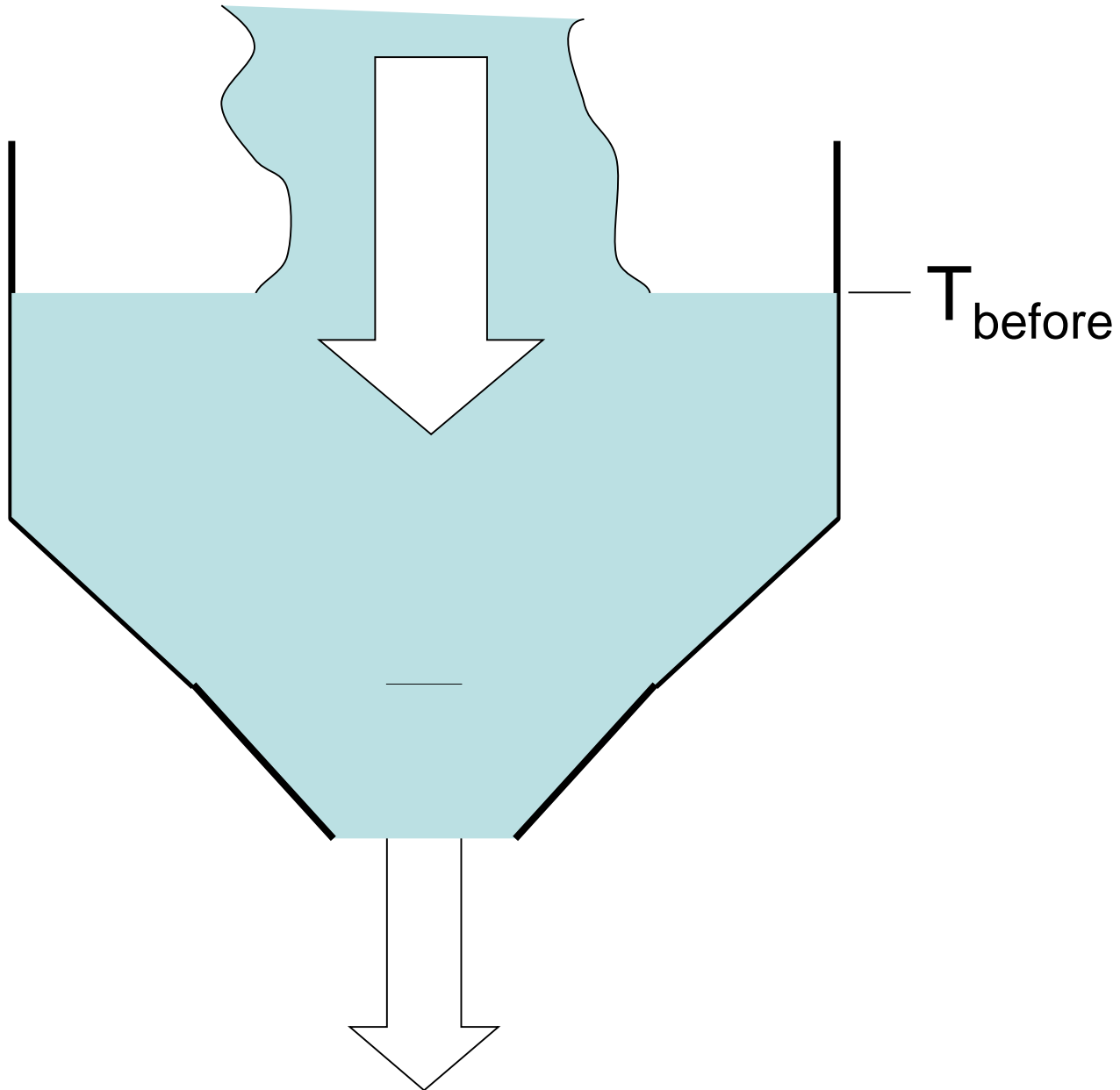
“Emission Height”



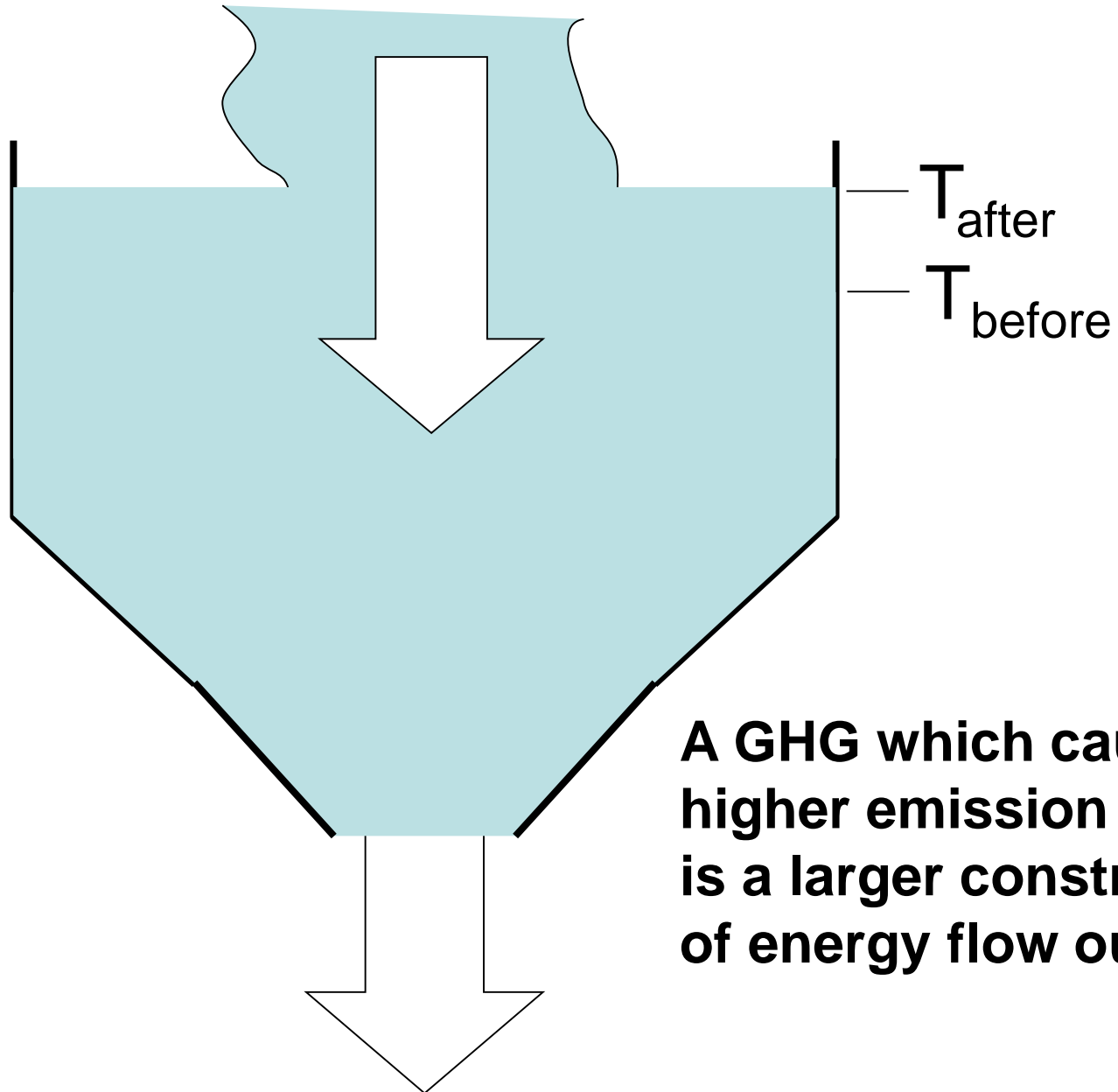
GHG Ranking: Emission Height (Location)



GHG Ranking: Emission Height (Location)



GHG Ranking: Emission Height (Location)



A GHG which causes a higher emission altitude is a larger constriction of energy flow out.

GHG Ranking Factors

- 1. Amount: more there is, potentially more radiation can be absorbed**
- 2. Ability: depends on the wavelength and GHG**
- 3. Location: both where in the atmosphere and where (λ) in the outgoing radiation spectrum**

Poll

W

Suppose you are Dr. Evil. You want to create a greenhouse gas and distribute the most effective GHG and then demand 1 million dollars to stop emitting it. What GHG properties would you seek?

Visual settings 

Activate 

Show results 

Show correct 

Lock 

Clear results 


Fullscreen 

 **Poll locked.** Responses not accepted.

A gas that absorbs strongly in the 20 microns, and remains concentrated low in altitude.

A gas that absorbs strongly at 11 microns, and is mixed to the upper troposphere

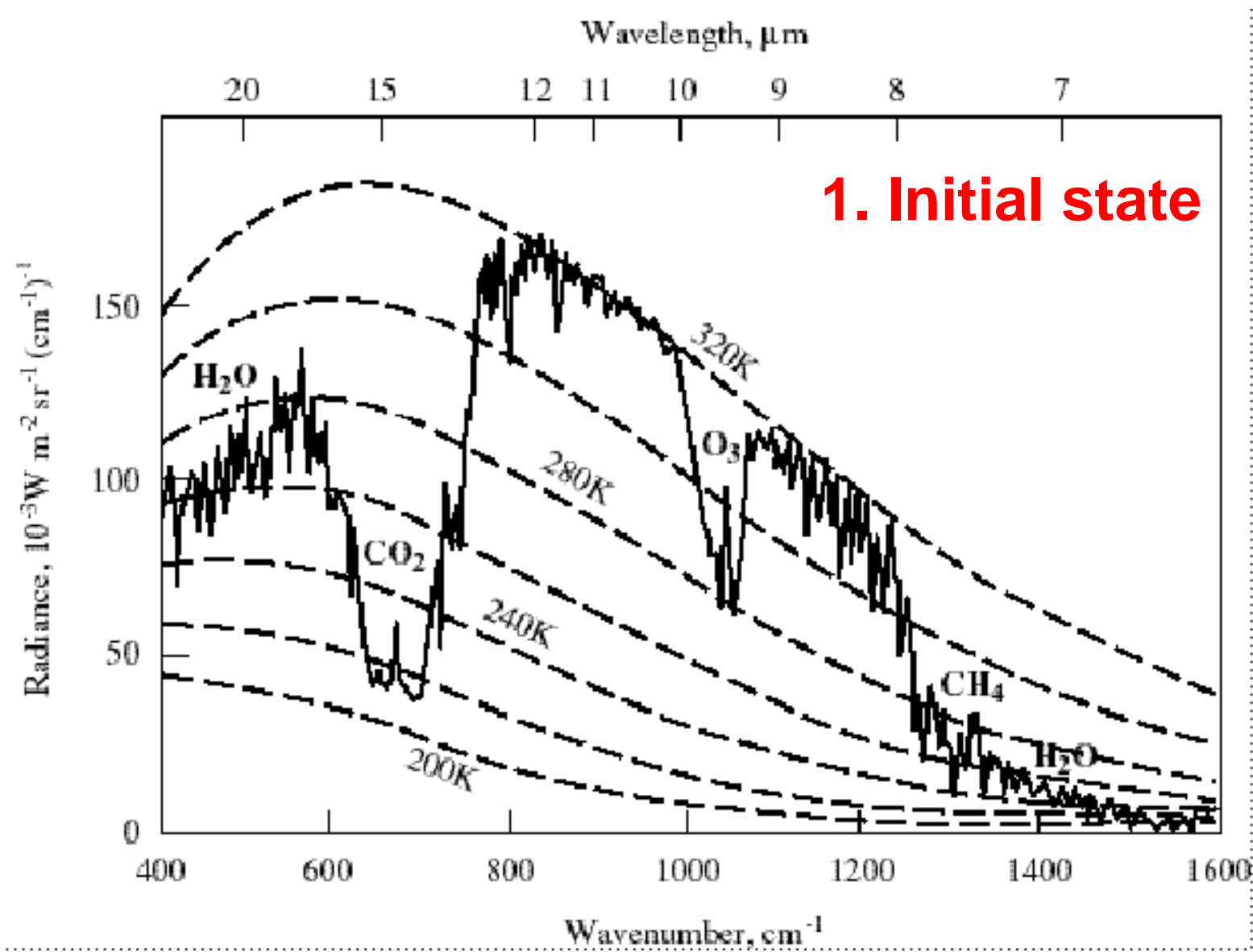
A gas that absorbs weakly in the IR to avoid band saturation

Next 

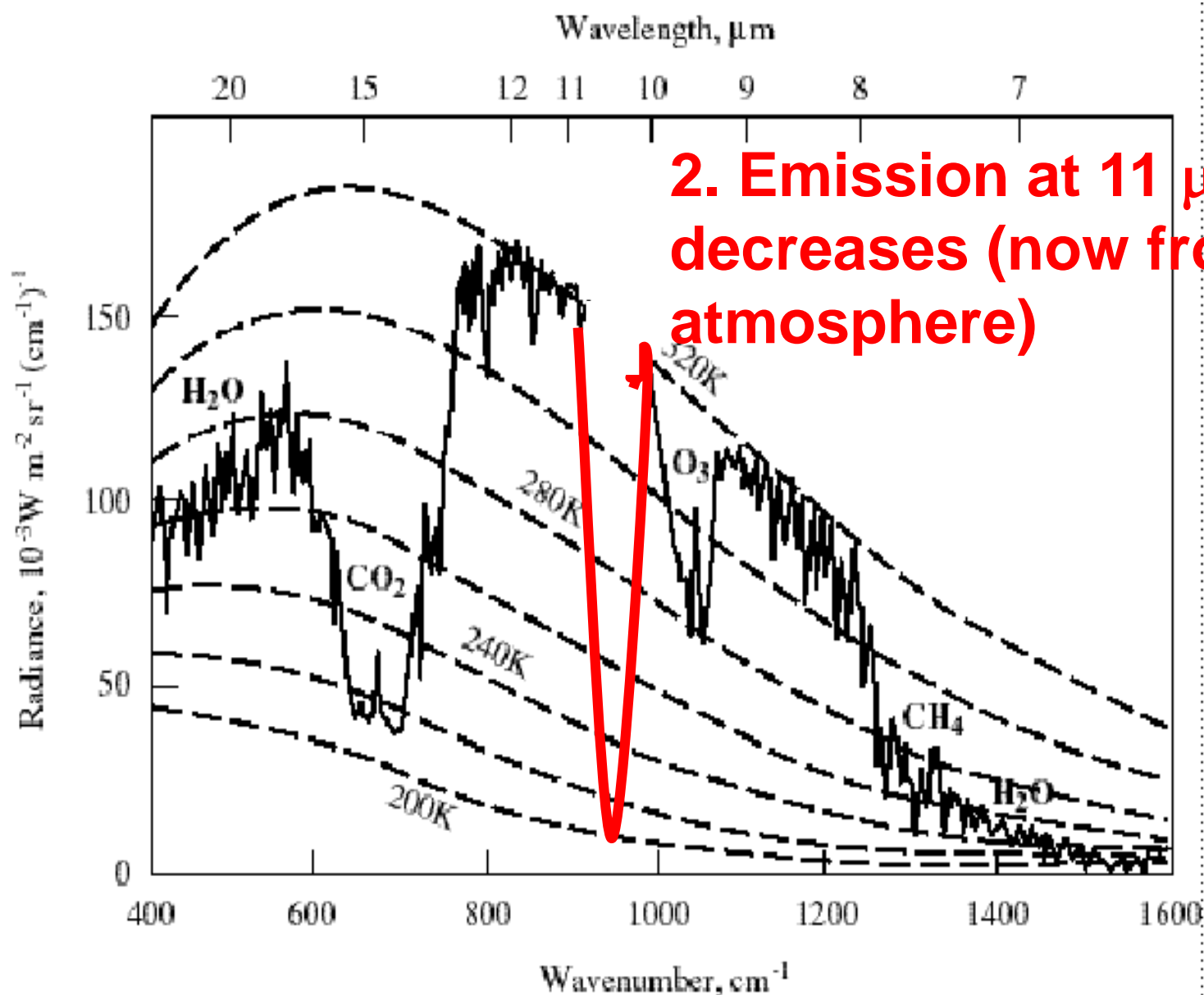
Previous 

Total Results: 0

Addition of a GHG Absorbing at 11 μm



Addition of a GHG Absorbing at 11 μm



2. Emission at 11 μm decreases (now from a cold atmosphere)

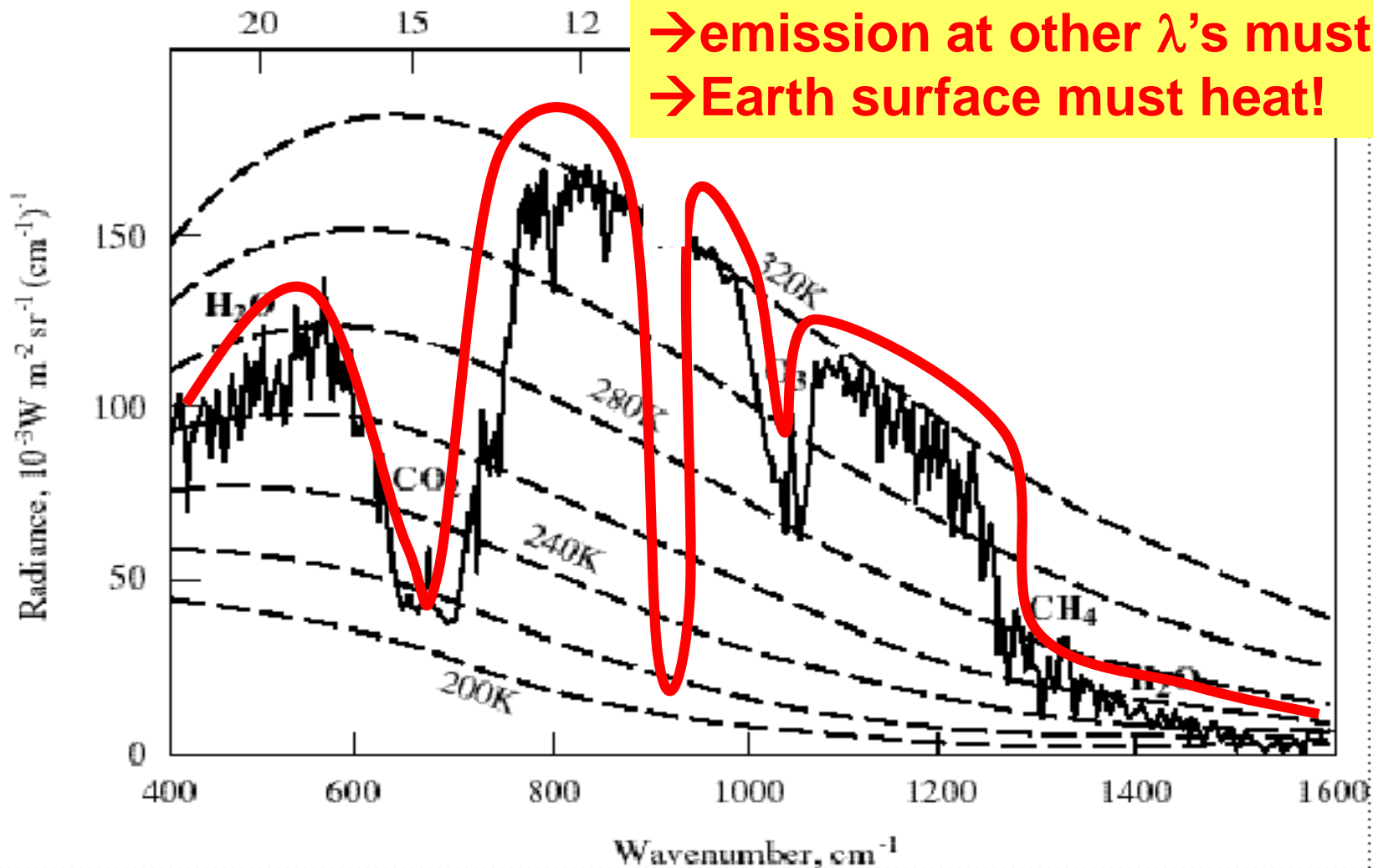
Addition of a GHG Absorbing at 11 μm

3. New equilibrium:

→ total emission must be same

→ emission at other λ 's must increase

→ Earth surface must heat!



An Analogy Perhaps?

[squeeze toy video](#)